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THE DRIFTS OF THE LAKE DISTRICT.

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ON THE DRIFTS OF THE WEST AND SOUTH BORDERS OF THE LAKE DISTRICT, AND ON THE THREE GREAT GRANITIC DISPERSIONS.

By D. MACKINTOSH, F.G.S.[1]

THE following is a continuation of the results of observations in the Lake District and neighbourhood, made during the greater part of last year, and the beginning of the present year.

Drifts around Whitehaven, Cleator, Egremont, St. Bees, etc.—About Workington, and farther south, the sea-coast zone of Criffell granitic drift (described in last article, GEOL. MAG., Dec., 1870, Vol. VII., p. 564) is very narrow, but to the S. of Whitehaven it becomes wider, and the great road from Whitehaven to Ravenglass, by way of Egremont, very nearly delineates its inland or eastern boundary. Boulders of this granite, along with porphyry (including the tesselated kind from the Caldbeck-fells), syenite from Ennerdale, etc., may be found on and in a red clay to the S.W. of Whitehaven, where the ground reaches a height of more than 400 feet above the sea, and is completely cut off from the Cleator and Ennerdale areas by the deep pass which runs from sea to sea between Whitehaven and St. Bees. On the brink of a quarried sea-cliff, about 300 feet above Saltom Bay, the Permian sandstone is planed, smoothed, and finely striated N. 30° E.

On the way from Whitehaven to Cleator Moor I saw many boulders of Ennerdale syenite, one of them measuring $5 \times 3 \times 3$ feet. On the E. side of the Ehen Valley, about 400 feet above the sea, the

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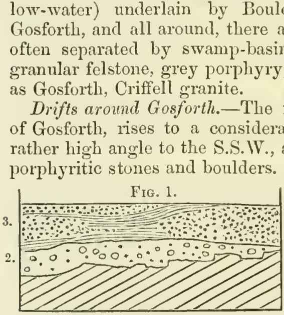
[1] It may be desirable to give a short explanation of some of the lithological terms used in this article:—*Granular felstone,* a fine-grained rock, mainly felspathic, with uneven fracture, and graduating from light grey (like the well-known Penmaenmawr rock) to a colour nearly black. This rock has often been erroneously termed both greenstone and basalt.—*Compact felstone,* a felspathic rock with comparatively even fracture, and often more or less flinty in appearance.—*Felspathic breccia,* a rock consisting of angular or irregular fragments chiefly of compact felstone, generally from one-fourth of an inch to two or three inches in diameter, sometimes much larger. It looks like petrified pork-shop brawn.—*Syenite,* a rock (in the Lake District) generally pinkish or reddish, and finer grained than ordinary granite, consisting of felspar, quartz, and hornblende, or two of these minerals. It is always intrusive, and passes into a rock approaching the character of greenstone.—*Granilite,* a convenient name for a very fine grained granite.

New Waterworks excavation has revealed blue clay (running into gravel), overlain by yellowish-brown clay, and containing boulders of Ennerdale syenite from the E., limestone from the W. or N., etc. In one place the striæ (on Skiddaw slate) run nearly E., in another, E.N.E., both pointing over high ground towards Ennerdale. The adjacent height called Dent, as previously stated, is covered with boulders of syenite and porphyry up to 1,100 feet. About Egremont there is an unknown thickness of unstratified or rudely stratified gravel, with stones and boulders of syenite, porphyry, slate, sandstone, a little Criffell granite, and enormous rough blocks of local limestone. Some distance N.N.W. of Egremont there is a red clay with glaciated pebbles and boulders, lying on a very uneven and uptorn surface of limestone rock. Farther N. there is a great thickness of clean gravel. On the table-land between Egremont and St. Bees, the drift is chiefly angular sandstone, tumultuously worked up from the rock below, and graduating upwards into a covering of clay and loam, sometimes rudely stratified, with boulders of greyish-blue porphyry, syenite, Criffell granite, etc. In St. Bees village there are some large boulders of syenite and porphyry.

Between St. Bees and the sea there is an array of abrupt drift-knolls, which reach a height of 100 feet, and might readily be regarded as moraines if they occurred at the mouth of any valley leading down from the mountains, or consisted of anything like moraine-matter, neither of which is the case. They are composed of sand, with highly contorted beds of unwashed gravel, which rise up from beneath the beach-shingle to the top of the cliff-section. This drift rests on reddish-brown Boulder-clay. Between St. Bees and Seascale there is a succession of mounds and plateaux of stratified and frequently contorted sand and gravel, more or less covered with blown-sand, and (as is evident from the boulder "scars" visible at low-water) underlain by Boulder-clay. Between Seascale and Gosforth, and all around, there are great knolls of sand and gravel, often separated by swamp-basins. The pebbles consist of dark granular felstone, grey porphyry, syenite, and, nearly as far inland as Gosforth, Criffell granite.

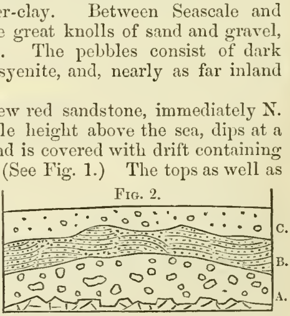
Drifts around Gosforth.—The new red sandstone, immediately N. of Gosforth, rises to a considerable height above the sea, dips at a rather high angle to the S.S.W., and is covered with drift containing porphyritic stones and boulders. (See Fig. 1.) The tops as well as

Fig. 1.



2. Red Boulder loam and sand.
3. Fine gravel, with irregular layers of sand.

Fig. 2.



A. Greenish or reddish brown, argillaceous, hard Boulder-clay.
B. Fine hard gravel and sand, with waved lamination, and many round stones.
C. Foxy-coloured loam, with very few stones.

the sides of the ridge, between the river Bleng and Wastdale, is covered with drift, consisting mainly of pinel, frequently overlain by foxy-coloured loam. A great part of this ridge must always have been beyond the reach of precipitated valley-glacial moraine-matter. The boulders, many of which are very large, are chiefly bluish-grey porphyry, probably from the high ground to the N.E., but in part, possibly, from concealed rock *in situ*. On this ridge there are so many glaciated boulders that I had no need to have recourse to the expedient once recommended to me by a Yorkshireman, who, after stating that there were no rounded and scratched stones in his neighbourhood, advised me to go to an adjacent sandstone quarry, where I could find plenty of square blocks which I could round and scratch for myself!

Drifts and Glaciated Rocks of Wastdale.—Between the neighbourhood of Gosforth and one-third of a mile W. of Strands, a fine-grained felspathic rock rises through the drift in bosses. Thence to Wastwater-foot, the rock is principally granilite, and this rock occupies a great part of the space between Strands, Buckbarrow, and Greendale. Near the lake it graduates northwards into a quartzo-felspathic rock.

In the neighbourhood of Kidbeck and Gap, contorted gravelly pinel, with stratified sand seams, and real typical pinel covered by foxy-coloured loam, may here and there be seen. Great numbers of surface blocks, both angular and rounded (as well as those imbedded), strew the ground, and rise up the slope to the summit of the Moor above Yewtree. At Gill, the pinel graduates downwards into rough angular breccia. The latter and the coarse local limestone and sandstone débris previously mentioned may possibly represent the first land-ice period. The stones and boulders about Gill are pink and light grey granilite, and a dark grey porphyry. Farther on, flat knolls of pinel, sometimes greyish-brown, run underneath the screes or fallen débris, with a distinct line of demarcation. Between Greendale and Wastwater, there are many *roches moutonnées*, which have been smoothed or glaciated chiefly from the E., sometimes E.S.E. and E.N.E., in a few instances from the S., in all instances obliquely or directly from the direction of the Screes escarpment. A glacier from the N.E. moving *along* the valley could not have accomplished this, either by its direct action or by a lateral process of grinding, as the configuration of the ground would have enabled ice from the N.E. to gain free access to what are now the jagged or lee sides of the bosses.[1] The idea at first suggested itself that a great stream of land-ice may once have tumbled over the Screes escarpment, and smoothed the above rocks in its passage across the dale. Mr. de Rance has expressed a similar idea (Geol. Mag. March, 1871), but I do not think that it can be reconciled with an attentive consideration of the physical geography of the district. The glaciation of rock-surfaces directly or obliquely across valleys is in many parts of the Lake District the general rule, and not the exception. Can it be explained by what Dr. Robert Brown calls "a monstrous regurgitation of waves," caused by ice falling down from the tops of cliffs or ridges, and struggling to become launched, at the time when the valleys were occupied by the sea?

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[1] Professor Phillips, some time ago, after a particular examination, came to the conclusion that no glacier could ever have flowed along the whole length of Wastdale (Geol. Mag. Vol. II. p. 513).

At one spot, near the lake, on the E. or upstream side of a glaciated boss of rock, a section has been exposed of a deposit of drift. (See Fig. 2.)

E. of Strands one may see plateaux and knolls of stratified and contorted sand and gravel, with sub-angular stones and boulders of granite from the E., and porphyry from the N. In some places pinel appears underneath. W. of Strands, a fine section of pinel, surmounted by loam, may be seen on the road-side. About a quarter of a mile W. of Strands, the granilite is distinctly striated E. 10° N., which accords with the direction above assigned to the glaciation of the bosses near Greendale.

Philosophy of Screes.—Wastdale Screes escarpment rises to an average height of about 1,650 feet above the lake. Near the top the slope is about 40°, in the middle 50°, towards the base 40°. The solid rock *generally* comes half-way down, and the broken rocks or screes run half-way up. The screes are chiefly in deltas, under rakes or gulleys, from which they have been precipitated by frost, or washed down by rain torrents. (See Fig. 3.) In the process of scree-making, the tops of previously-existing cliffs have been bevelled off, and their bases shored up. At the lower end of the lake the Screes consist of greyish-blue, sometimes nearly black, fine-grained felstone graduating into ill-defined porphyry. Pebbles and boulders from the Screes may be readily traced all the way S. as far at least as Chester, their derivation being witnessed by the peculiar granilite and granite with which they are associated.

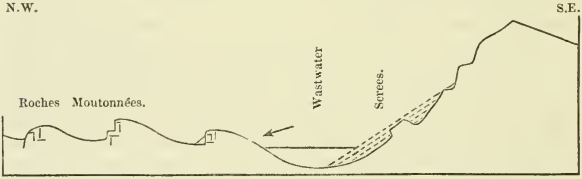


Fig. 3.—Section of Wastdale.

With the exception of a very little comminuted matter, which in some places has been washed down from above, the Screes have not been mixed with fine sand or clay. They nearly all consist of bare stones. Rain cannot grind stones, and the lake is almost equally incapable, as may be seen at its lower end, where it has thrown up a heap of very small, bare, angular fragments, with three terraces marking different water-levels. The brook from Illgill, above Wastwater-foot, has made a section in scree-matter (a part of which it has probably itself brought down), revealing its bare stony character. In the greater part of the Lake District, the screes are bare fragments of rock, and continue so after becoming covered with certain kinds of vegetation. Where glaciers were able to collect moraines, these screes would supply them, and the re-precipitated screes or moraines would be hillocks, banks, or ridges of bare stones. But in those exceptional cases where ochreous matter, or previously comminuted drift from the tops of cliffs or sides of steep slopes (or matter arising from the chemical decomposition of certain kinds of rocks), might be washed down on the surfaces of glaciers, the moraines would still be distinct in their composition and structure from plateaux and knolls of elaborately ground-up pinel, with smoothed, rounded, polished and striated stones and boulders. The term moraine, therefore, ought never to be applied to an accumulation of Boulder-clay, unless indeed it be coupled with the word *profonde*, supposing the writer adheres to the theory that Boulder-clay was formed *under* land-ice.

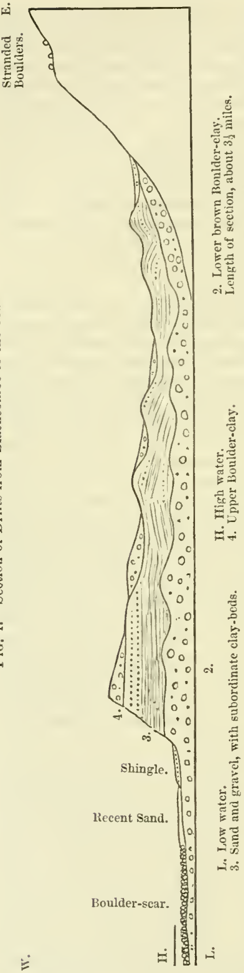
The Eskdale Granitic Area.—E. of Wastwater-foot the granilite runs into, and here and there (between Red Brow and Beckfoot, for instance) alternates with the very coarse-grained granite of the Eskdale fells. The latter is very confusedly crystalline, with much greasy-looking quartz, ill-defined crystals or patches of felspar, and so very little dark mica, that a block of this granite often looks nearly as white as chalk. In many places, as in Muncaster fell, it has more or less of a reddish hue. In Irton Park, between Santon Bridge and Steathwaite, there is a succession of rounded, but nowhere distinctly moutonnéed granitic bosses, with tails of hard unwashed gravel surmounted by stratified gravel and sand. On the S.W. side of Irton Pike there are great masses of stratified and false-bedded gravel and sand overlying rudely stratified pinel with enormous boulders. On going down from Irton Pike to Keyhow, real argillaceous pinel or Boulder-clay may be seen on the road-side. E. of Red Brow the locally-limited granilite is decidedly moutonnéed in the direction of the valley. The cliffs of coarse granite on the N. side of this part of Eskdale, rise to a considerable height, and their bases are strewn with myriads of massive blocks, the successors of as many myriads which were probably floated off during the glacial submergence, and which may now be found scattered as far south as Trescott, near Wolverhampton. There is no vestige of a glacial moraine in the lower part of Eskdale.

Drifts between Irton, Drigg, and Ravenglass.—Eskdalefell granite has found its way a short distance to the west of a line drawn from Irton to Drigg, where it has been mixed up with Wastdale dark granular felstone and granilite, and to some extent with Criffell granite. These rocks may be found not only as boulders, but as pebbles imbedded in great knolls of sand. Red, stiff, hard lower Boulder-clay makes its appearance at the railway-station and on the sea-beach at Ravenglass. East of Muncaster High School there is a great expanse of triturated granite, with many stones of granite, slate, porphyry, sandstone, quartz, etc., rudely stratified and dipping at a greater angle than that of the slope,—the whole suggesting a meeting place of tides or currents. On the east side of the trumpetshaped mouth of Eskdale there are many fine cliffs, and slopes strewn with large cubical blocks of granite, which would furnish a future ice-laden sea with great cargoes of boulders for transportation in a southerly direction.

Drifts between Blackcombe and the Sea.—From the mouth of Eskdale, a stream of mixed drift, with large granite boulders, runs southwards over the country between the mountains and the sea. Much pebbly gravel and sand covers the longitudinal depression between Blackcombe and the higher ground bordering the sea. It rises here and there into knolls separated by swamp and peat basins, and in some places is covered by, or alternates with, Boulder-clay. Nine out of ten of the large boulders on many parts of the west slope of Blackcombe (on the surface or imbedded in drift) are Eskdale granite or granilite, and Wastdale granilite. A beach of drift, with a foundation of pinel in some places, runs along the base, and rises up to 500 or 600 feet on the side of Blackcombe. North of Whitbeck this beach consists of well-rounded gravel and sand, which, in one flat-topped knoll, must be 120 feet thick. There are other abrupt sand and gravel eskers farther north. Many boulders of Eskdale granite choke up the mouth of Holebeck gulley, where they have been mixed with the granilite *in situ* discovered by Mr. Marshall, of Leeds.

Mr. Eccleston, of Carlisle, some time ago discovered a stream, or rather a series of groups, of granite blocks, running from the fells on the east side of Eskdale along the ridges and slopes as far as the southern extremity of Blackcombe, and reaching a height of at least 1000 feet above the sea.[1]

Fig. 4.—Section of Drifts from Blackcombe to the Sea.



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[1] I afterwards saw two of these ice-floe loads, the principal one being on a plateau,

Some of the finest sections of drift in the north of England, though often much obscured by talus, may be seen on the sea-coast adjacent to Blackcombe. (See Fig. 4.) For more than three miles the cliff-line consists of stratified sand, gravel, and Boulder-clay. For at least two miles (walking north from the neighbourhood of Silecroft), the sand attains a thickness of from 100 to 120 feet, exclusive of blown sand. Here and there it contains layers of gravel and subordinate beds of clay. In many places it is capped with upper Boulder-clay. (See Figs. 5 and 6.) Northwards, the upper clay here and there swells out to a great thickness, and the lower brown Boulder-clay rises up to a considerable height above high water-mark. At the most northerly point I visited, the latter terminated abruptly under a series of steeply-inclined beds of sand. (See Fig. 5.) The lower clay contains more boulders and is more argillaceous than the upper, excepting where it runs into a bright red clayey loam similar to what may be seen on the beach at Blackpool and elsewhere. The three drifts contain granite, along with many other erratics.

Fig. 5.

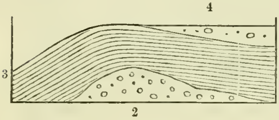
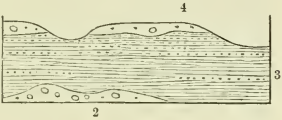


Fig. 6.



Sections illustrating the mode of occurrence of Drifts on the coast near Blackcombe.

2. Lower Boulder-clay. 3. Sand and gravel. 4. Upper Boulder-clay.

Boulder-scars.—From Maryport to Parkgate, the E. coast of the Irish Sea at intervals exhibits accumulations or concentrations of large boulders, which are locally called scars. They may be seen in all stages of formation, from the denudational area, where they are in course of being left by the washing away of the clayey matrix, to the depositional area, where they have become half-covered with recent sand and shingle. In many places (as between Seascale and near Silecroft) there are so many boulders within a small area as to show that a considerable thickness of the clay must have been removed. With the exception of having tumbled down as the cliffs were undermined and worn back by the sea, many of the boulders may still rest nearly in the positions they occupied in the clay, but (as is evidenced on the coast at Parkgate) others, up to a great diameter, may have been shifted horizontally. Some of the scars exist where the Boulder-clay would appear to have risen up into

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on the south side of the upper part of Fossbeck, at a height of about 1000 feet, and in a situation where one might almost see the boulders in course of being stranded. One measured 8 × 7 × 3, another 6 × 4 × 3, and a third 10 × 8 × 4. They were accompanied by a few boulders of other rocks.

ridges or mounds, as no clay is now found opposite to them at the base of the sea-cliff. Others are clay and boulder plateaux, visibly connected with the cliff-line. Most of the scars, I believe, are remnants of the great Lower Brown Boulder-clay. The most conspicuous boulder in the scars S.W. of Bootle, is Eskdale-fell granite, accompanied by a little Criffell granite, and a great number of the usual felspathic erratics.

Drifts near Silecroft and Holborn Hill.—The Eskdale granitic drift near Silecroft suddenly bends round and runs up Whicham valley for some distance E. of the Parsonage. The S.W. end of Millom Hill (which chiefly consists of cleaved felspathic ashes, granular felstone and porphyry), presents the appearance of a beach strewn with many pebbles of granite and other rocks. Here I saw a *roche moutonnée* with its glaciated side towards the hill, but not in the line of any valley. On the adjacent plain there is much granitic drift. Its inland boundary bends eastwards to the N. of Holborn Hill, crosses the Duddon estuary, and re-appears on Dunnerholme Island, and near Soutergate. The boundary then runs S.S.E. by Great Urswick, a little N. of which I found a granitic boulder.[1] Pebbles of it (probably washed northwards along the sea-coast from its original boundary S. of Baycliff) may be seen near Bardsea. Between Millom Station and Millom Hill, the Upper Boulder-clay knolls apparently alternate horizontally with sand and gravel knolls, but the few sections visible justify the supposition that the two drifts thin out below or above one another in a manner indicating distinct periods of deposition. Between Millom Station and Silecroft, a similar dovetailing of drift-knolls may be recognized, and in one part of the railway-cutting the sand is interstratified with subordinate beds of clay, but not Boulder-clay.

Striated Limestone crossed by Drift-carriage.—About half-a-mile S. of Millom Station, a gently-swelling eminence, 75 feet above the sea, has lately been quarried, and the result has been the exposure of the most thoroughly, continuously, and extensively glaciated rock-surface I have yet anywhere seen (Nov., 1870). The grey limestone has been uniformly planed down, polished, and traversed by white grooves and striæ. The finer lines have been cleanly cut, but in many places the coarser striæ and grooves (the latter about $\frac{1}{8}$th of an inch in breadth) consist of a close succession of rough dints, as if small, sharp, angular quartz fragments had been made to roll over, or as if the floating ice which held the fragments had vibrated after suddenly grounding (?). One might suppose that the polishing of the rock and the microscopic lines were produced by land-ice, were it not that the latter cross each other at nearly all angles.

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[1] The boundary in Furness, and in many places further North and South, must have been more or less deeply submerged, and one cannot long trace drift-boundaries without having to abandon the notion that they must always have been marked by dry land, or that dry land necessarily existed where there are driftless areas.

Most of the lines visible to the naked eye point N.E. or obliquely across the valley of the Duddon. Most of the few strongly-marked grooves run between N. and N. 35° E., or approximately in the main direction of the Duddon valley. The ramifying rough crevices in the limestone would appear to have existed before the glaciation occurred. They are partly filled with sand and fine gravel, which may belong to the Middle Drift period, and which may have once covered the whole rock-surface, and furnished the ice with grinding material. If so, its removal by the ice must have been followed by the accumulation of the Upper (?) Red Boulder-clay which covered the glaciated rock-surface, and still covers it where quarrying operations have not extended. But this clay did not result from the grinding up of the limestone, for (according to an analysis made by Mr. Heywood, of Millom) it contains silica 62·97, and alumina, 17·50 per cent. Nearly all, if not all the stones and boulders in this clay, have come from directions which cross the grooves and striæ (a few of the microscopic lines excepted), and the main direction of the ice-marks (N.E.) is nearly at right angles to the main direction of the drift-carriage (N.N.W.). The glaciating agent, therefore, could not have been the carrying agent, though it may have been of the same nature. The boulders are chiefly Eskdale granite and Eskdale or Wastdale granilite, granular felstone apparently from Wastdale, etc. The existence of the striæ under a covering of Boulder-clay furnishes an illustration of one of the fundamental principles of geology, namely, that the sea preserves the most delicate marks on rocks in *areas of deposition,* a principle which Mr. de Rance overlooked when he asserted that the *roche moutonnée* at Grange Bridge could never have been touched by the sea (GEOL. MAG., March, 1871).

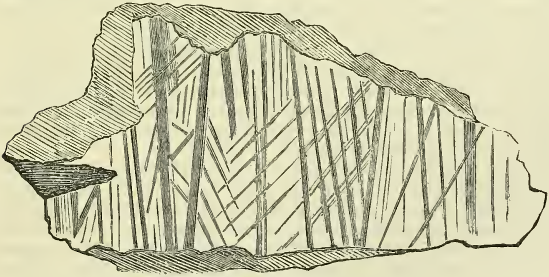

FIG. 7.—Glaciated Block of Limestone from the Rock-surface of a Quarry near Millom. Scale, one-fifth of original.

Limestone Sculptured by the Sea.—Not far from the above quarry, at Hodbarrow Point, the pebbles and boulders of the red clay are used by sea-waves to hollow out the originally rough and uneven surface of limestone strata, and the effect produced is a perfect facsimile of many of the smoothly sculptured rocks one may see in all limestone districts, where the irregularly pitting and roughening action of rain-water and frost has not obliterated the evidently ground-out basins and channels. On the hill-slopes between Silverdale Station and Yealand, and in many other places around Morecambe Bay, the Silurian grit pebbles may still be found in the hollows they once ground out. Under drift the sculptured limestone surfaces often become decomposed, while in the open air, in situations where rain-water innocuously runs off, they have remained nearly intact.

Valley of the Duddon.—Beyond the northern boundary of the granitic drift stream above described, and on the way to Thwaites, there are immense boulders of felspathic breccia, ashes, and porphyry. W. of Green the striæ run E. 30° N. I have elsewhere noticed the great pinel knoll near Green. About Thwaites there are many knolls and slope-coverings of pinel, with boulders up to eight feet in average diameter. Here, and all along the W. side of the Duddon estuary, there is much green, grey, and blue porphyry, *in situ*, along with ribboned or banded felspathic slag, felspathic breccia and felspathic ashes; and a tributary ice-laden current may have carried boulders of these rocks into the great drift-current already mentioned. Between Thwaites and Duddon Bridge there are numerous *roches moutonnées* on the slope rising from the W. side of the flat bottom of the Duddon valley, and among them we have the old story repeated, namely, the obliquely-upward glaciation of rocks *from* and *not along* the valley. The transverse configuration of the ground shows that (in many instances at least) the glaciation did not result from lateral grinding exerted by a valley-glacier, and it is worthy of remark that the direction of this glaciation approximately corresponds with the striæ W. of Green and at Millom quarry. The eastern slope of the upper valley of the Duddon is covered with a succession of gently-swelling knolls (with rocky nuclei) of pinel, and overlying loam, both containing large boulders. In many places there are *roches moutonnées*, with parallel undulations or wide ⌣-shaped grooves (as well as minute striæ), pointing N.N.E. or nearly in the direction of the valley. But the great wonder of the Duddon valley is the

Lateral Moraine near Seathwaite.—On walking along the road near Seathwaite Church, in company with the Rev. F. A. Malleson, of Broughton-in-Furness, and Mr. Postlethwaite, a neighbouring squire, I was almost astounded at the appearance presented by what at first looked like a black causeway of large blocks thrown down in haste by a pre-historic race of giants, and I could not believe that the spectacle was natural, until Mr. Postlethwaite assured me that it was so. It runs along the grass-covered (and apparently drift-covered) slope which rises gently from the east side of the valley to the ridge called Walna Scar. There are no rocky scarps above from which the blocks could have tumbled down. They are nearly all quite angular, and are rudely congregated, often piled on one another, within a well-defined zone, a few scores of yards in breadth, and about two miles in length. At the northern end this post-marine lateral moraine (for such evidently it is) rises up to about 300 feet above the bottom of the valley. At the lower end it descends nearly to the bottom of the valley. N. of it, and at a higher level, there are numerous rocky scarps from which a shallow glacier may have collected the blocks. But they may have been partly derived from the tributary glacier which once evidently came down through Seathwaite tarn cwm, which left many perched blocks on the platform in front of the cwm, and finally deposited the small irregular moraine which, with solid rock at intervals, dams back the water of the tarn.

Notes on the Drifts of Furness.—I have described these drifts in the Quart. Journ. Geol. Soc. vol. xxv., and would here very briefly state the results of a second series of observations. The greatest masses of yellowish-brown pinel I have yet encountered are near Lindal, at a height of about 300 feet above the sea. They reach a thickness of about 120 feet, and, at a lower level, a still greater thickness is said to have been proved. It resembles the pinel which runs under the sea on the E. coast of Furness, and is evidently on the same horizon with the Lower stony Boulder-clay of Blackpool. In Furness we find what may be called the central and maximum development of this formation, and it graduates northwards into the pinel of the Coniston Old Man (which, on the Walna Scar road, rises to a height of at least 1200 feet above the sea), and southwards into the more sedimentary Lower Boulder-clay of Lancashire. In no part of the N.W. of England, so far as I have seen, is there any appearance of a line of demarcation between the pinel of the hill-slopes and the adjacent recesses and valleys, and the Lower Boulder-clay of the plains. The erratic boulders in the pinel at Lindal, Ulverstone Railway Station, the sea-coast near Bardsea, etc., would appear to have come in straight or curved lines from Millom Hill, and the slopes thence stretching Northwards to Duddon Bridge.

Dispersion around Hill-bases and up Valleys.—Beaches of pinel curve round the small hills and run up the small valleys N. and N.N.E. of Ulverstone. Most of the imbedded boulders are local, but a few, consisting of porphyry, would appear to have come from the W. side of the Duddon valley. It is difficult to conceive of their having come in a straight line over the elevated intervening hilly district, and no similar erratics, so far as I am aware, are to be found on the higher plateaux or passes of this district. We may, therefore, infer that these boulders were floated round by way of Ireleth, stranded on the jutting sea shores near Ulverstone, and carried up the small valleys by ice-laden flow-tides or wind-currents. But the lateral or *up-valley* dispersion of portions of drift diverted from the borders of great ice-laden currents has been a common and not merely an exceptional occurrence in the N.W. of England.[1]

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[1] In E. Lancashire, along the boundary of the great North-western drift, boulders have found their way into valleys lying at nearly right angles to the general course of the drift. Far up in the narrow valley called Swineshaw, near Staley Bridge, there are many stones of Eskdale granite and Wastdale granilite which reach a height of 900 feet above the sea. They are associated with stones which must have come from various points of the compass.

From Greenod to Newby Bridge.—At Greenod, on the west side of a tidal channel, we may see a miniature illustration of the fact, that when angular fragments get imbedded in loam or clay, they soon lose all chance of ever becoming rounded,—a fact of much importance in speculating on the origin of hill-side drifts. In Haverthwaite Schoolyard a boss of rock has been glaciated from E. 30° N. Near Newby Bridge Cottages, the slate rock in the railway cutting is polished and striated between N. 40° E. and N. 60° E. Farther north, at the foot of Windermere Lake,[1] the striæ run N. 20° E. The glaciated surface is covered with well-rounded gravel and sand, and a little pinel fills up the underlying rough cavities. The drift here swells out into great knolls, which rise at least 100 feet above the level of the river.

Around Silverdale, Burton, and Milnthorpe.—Near Silverdale Station the limestone has been striated from the N. Between here and Yealand, more or less rounded limestone boulders may be found in positions where they might easily be launched, as many of their fellows probably were, by coast-ice. But the most wonderful array of limestone boulders, some of them 15 feet in average diameter, may be seen on the south side of Farlton Knott, near Burton. On walking from Burton to Heversham, I unexpectedly met with a great number of boulders of Shapfell granite, one of them $4 \times 3\frac{1}{2} \times 2\frac{1}{2}$ feet. They are abundant at and near Whasset, and all round Milnthorpe, but I saw only one pebble of this granite farther E. than the neighbourhood of Whasset.[2] The granite has come from about E. 15° N. or from Wasdale Crag, and I think it must be something more than a coincidence that this is nearly the general direction of the truly remarkable

Parallel Drift-ridges S.E. of Kendal.—The N.N.E. direction of these ridges (which are well represented on the shaded Ordnance Map) not only points to Wasdale Crag and the neighbourhood, but across a series of notches on the intervening crest of Whinfell Beacon and Greyrigg Forest (1544 and 1619 feet above the sea). On the watershed between Kendal and Low Gill, many of the ridges point in various directions, and this is the case with most of the ridges in the neighbourhood of the River Lune. At the mouths of Long Sleddale and Bannisdale (where Shapfell boulders have been found) most, though not all of the ridges point approximately N. and S. Over a considerable area S.E. of Kendal, and further S.

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[1] I may here remark, in answer to Mr. de Rance, that while in Bowness and the neighbourhood, I ascertained from various persons, who were thoroughly acquainted with all the ins and outs of the lake, that none of the detritus or sediment brought in by the Brathay river can find its way through the lake to the lower end, and thence to the sea; and one reason assigned was that the currents generated by wind, etc. (which often reach a great depth, as proved by net sinking), more frequently flow from the S. or up the lake, than from the N. Lacustrine deposits, which have all resulted from the action of fresh-water, afford the only true measure of subaërial degradation since the Glacial period.

[2] I never saw any Shapfell granite farther S than the road between Yealand and Silverdale. Professor Phillips mentions its occurrence in a canal S. of Lancaster. Within the area of the great North-western drift, farther south, a certain kind of Dalbeattie (Criffell) granite might be easily mistaken for Shapfell.

than Milnthorpe, the ridges are wonderfully parallel, and point, as already stated, N.N.E. It is certain that many of these ridges have rocky nuclei, and that many at least of these nuclei ran in the above direction before the Drift period is probable from its near coincidence with the larger axes of Benson Knott (1035 feet), New Hutton ridge (1097 feet), etc. The parallel drift-ridges vary in height from 20 to 30 feet near Burton Railway Station to more than 100 feet near Milnthorpe, and in the area where their parallelism is best defined between Farlton Knott and Oxenholme. As a general rule, the more northerly ridges consist chiefly of Boulder-clay, which (as between Oxenholme and Low Gill) rests on alternately jagged and glaciated rock-surfaces, but their shape has been completed, and their final direction given by an addition of gravel and sand. About Oxenholme Station, a great part, if not the whole, of some of the ridges is made up of stratified gravel and sand, and this remark applies more or less to the ridges further E. and S. The gravel in many instances is well rounded, in others subangular. Between Milnthorpe, Burton, and Carnforth, where I have more particularly examined them, the ridges, so far as can be seen, are all sand and gravel, with subordinate beds of red loam or loamy clay. I have been assured that, near Milnthorpe, the ridges, at some depth beneath the surface, contain a great thickness of sand. The low oblong knolls rising out of the peaty and marshy flat stretching W. and S. from Burton Station are of the same character as those which rise to a greater height in the neighbourhood. The hollows around these knolls were probably once occupied by a lake which gradually became filled up until conditions favourable to the growth of peat originated. But the knolls are distinct in shape, composition, position, and magnitude, from any deposits to which a small (or even a large) lake could ever have given rise, and are evidently a low-lying con-

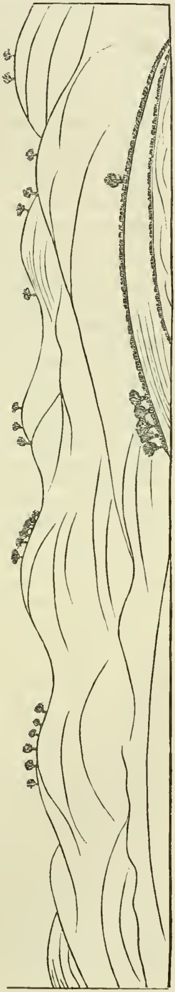

Fig. 8.—Parallel Drift-ridges, looking N.N.E. from the Railway Bridge, northwest of Holme.

The Revd. M. H. Close and Mr Kinahan now admit that the shape of their drumlins was partly given to them by the sea.

tinuation of the sand and gravel ridges further north, and the Carnforth sand and gravel knolls further south.

The ridges under consideration are, generally speaking, not *linearly* parallel. In the same line an oblong hollow is succeeded by an oblong eminence, as if the eminence had been partly formed by the abstraction of matter from the hollow, but this may not necessarily have been the case. Most of the stones and boulders as far S. as Yealand have come from about N.N.E., and consist chiefly of upper Silurian grit or mudstone, and some porphyry, breccia, and dark felstone (from near Wasdale Crag, ?). At Carnforth, further S., the stones and boulders are nearly all limestone, which likewise probably came approximately from the N.

From these facts it may be inferred that the ridges may possibly represent three periods—the period when the rocky nuclei were formed by denudation—the period when the Boulder-clay was arrested by these nuclei—and the period when the sand and gravel which partly or entirely compose the ridges were deposited. However this may be, it may, I think, safely be asserted that *the present aspect and parallelism of the ridges* is due to the agency which deposited the sand and gravel, or to marine currents with or without floating ice; and this view of their formation may be applied to the curved parallel ridges which ramify like a fan from the neighbourhood of Wasdale Crag, and which have probably been finally shaped by the current that distributed the granitic boulders.

Southerly Extension of the Great N. Western Drift.—The Wasdale Crag and Carnforth[1] drift-stream would appear to have nearly, if not altogether, terminated a little S. of Lancaster. Some distance further S. the ground was monopolized by the great drift stream from the N.W., already described. This stream may have received some slight contributions from the N.N.E. stream. Among the boulders exhibited in Peel Park, Salford (nearly all of which were found in the neighbourhood), I detected many old Cumberland acquaintances. The following is a rough estimate of the relative per-centage of the larger boulders, which I made with the assistance of Mr. Plant, F.G.S. :—Felspathic trap running into porphyry and breccia, 50; Silurian grit (apparently from Furness) and local sandstone, 30; Eskdale fell granite, 19; Criffell granite, 1;=100. To the east of Manchester I have seen no Criffell granite. At Snape Green brickyard, near Southport, the Criffell seemed to preponderate over Eskdale granite. (For further remarks on the southerly extension of the north-western drift see explanation accompanying the Map, p. 312.)

General Results.—From the facts stated in the eight articles I have written on the Drifts of the N.W. of England,[2] I think it may be inferred that land-ice may have planed, smoothed, polished, and striated rock-surfaces, and pushed loose débris forward to the nearest protected situations, but that rounded, smoothed, and polished boulders must have been chiefly shaped by floating-ice and sea-waves,[1]—that floating or ground ice glaciated a great part of the Lake-district; that the four drifts were deposited by the sea and floating-ice, though more or less of the clay and loam composing them may have originated as subglacial mud; that the blue clay was accumulated under a comparatively shallow sea, and denuded (if not upheaved and again depressed), before it was overlaid by the pinel or Lower Brown Boulder-clay; that the middle sand and gravel were accumulated during the gradual *rise*, and not during the fall of the land, as Mr. de Rance believes; that the Upper Boulder-clay of the

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[1] The finest sections of sand and gravel I have yet seen are at the Carnforth Railway Station, and on the Canal side. At the latter place there is gravel above and below, and sand in the middle. At the village, a great deposit of sand contains enormous limestone boulders, one of them $9\frac{1}{2} \times 9\frac{1}{2} \times 5$ feet. In addition to limestone, in the Carnforth drifts, there are Silurian grits and volcanic rocks from about N.N.E., and Carboniferous grits, etc., from the N.E.

[2] Geol. Mag., August, October, December, 1870, and February, June, and July, 1871; Proceed. W. Riding Geol. Soc., 1870; Quart. Journ. Geol. Soc. vol. xxv.

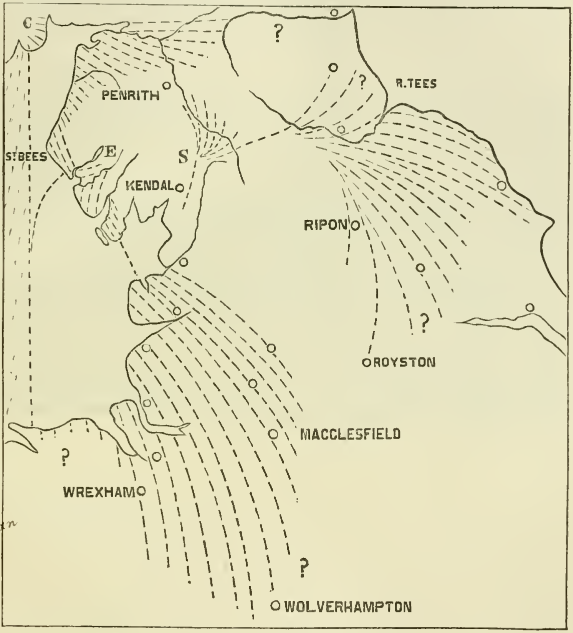

FIG. 9.—Map of the Three Great Granitic Dispersions in South Britain. (Explanation on page 16.)

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[1] According to Forbes no *actual* glacier is capable of smoothing or polishing boulders, though by means of a gritty base it may smooth and polish rock-surfaces.

plains, which I believe to be equivalent to the foxy-coloured loam of the mountains, was deposited (in many places on the extensively denuded surface of the middle drift) during a succeeding submergence, the vertical extent of which was at the very least 1300 feet; that after the land again rose, glaciers lingered in the inner and upper valleys and cwms of the Lake-district, but that they did not reach a great length, or leave many extensive moraines; that during a great part (though not the whole) of the Glacial period in the Lake-district and W. Yorkshire, the conditions were similar to those now prevailing in nearly the same latitude, in the Baltic Sea, and in the Atlantic off the coast of Labrador.

Map of the Three Great Granitic Dispersions in South Britain.—C, E, S, the sources of the Criffell, Eskdale, and Shapfell (Wasdale Crag) Dispersions. The left hand finely dotted line represents the possible western boundary of the Criffell and Eskdale drift. According to Curry, the Criffell drift extends further eastwards than I have mapped it. According to Buckland, the Shapfell drift ramifies (as represented) to the neighbourhood of Durham. Green is my authority for the Shap boulder at Royston. I found granite near Longridge (a few miles N.E. of Preston), at Rochdale, the upper reservoir, Swineshaw valley, and at Stockport. Many boulders of granite have been found by Mr. Sainter at Macclesfield. Granite has found its way to an altitude of more than 1100 feet on Holcombe Hill, north of Manchester (Mr. Eccles). It has been discovered by Dr. Alexander at Mitholmroyd, east of Todmorden, and by Mr. Green in the Wye Valley, Derbyshire. These straggling dispersions are not included in the map. Trimmer has found stones of granite decreasing in size and numbers from Chester to Conway. Ramsay thinks that the foreign drift of Anglesey came from the N.N.E., so that the western boundary of the granitic drift in the map may not represent the extreme limit of the dispersion. I have traced the western boundary from near Pentre Halkin, Flintshire, to Padeswood Station, near Mold, and a short distance to the west of Wrexham. There are many large boulders of granite at Farndon, eight miles south of Chester. They are chiefly Eskdale granite. though Criffell is not altogether absent. Five out of six of them are intensely glaciated, whereas in Eskdale not one out of six can be said to be well glaciated. Between Wolverhampton and Bridgenorth there are numerous boulders and angular blocks of granite, some of which are four feet in average diameter.

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